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Psychological Aspects Of Jets

Tension Stresses Affecting Pilot Performance Exist In All Aircraft, But Studies Indicate They Are Intensified In Modern, High Performance Jets

By Neil D. Warren
University of Southern California

About seven years ago a research group at the University of Southern California was asked to consider a problem in jet fighter operation. It had been observed, both among U. S. Air Force pilots and among those flying jets in other countries, that they were experiencing much more fatigue than they encountered in comparable flights of conventional aircraft. As a preliminary step in this research, our group interviewed a large number of jet fighter pilots and found that they did indeed report more fatigue than they had experienced in propeller-driven fighters.

A later study by ARDC was directed at the question of fatigue in the B-47. Here again the interview method was used and it was found that 25 percent of all pilots interviewed indicated that "flying the B-47 fatigued them more than did flying any previous bomber in their experience."

This finding represents a major difference in the experiences reported by pilots of jet aircraft. While it is obvious that jet transports will differ from jet fighters and the B-47, it seems important to examine the causes of the general fatigue experienced and to consider ways of dealing with it.

Causes Of Fatigue

In the first place, the duration of flights was generally shorter in the jet aircraft even though the fatigue was greater. The average length of flights for the B-47 pilots who complained of the greater degree of tiredness was less than six hours. They claimed that flying the B-47 made them more tired than flying any other bomber for a considerably longer period of time.

The investigators for ARDC believed that they could rule out differences in experience, differences in age, kind or amount of personal equipment, and even the "cramped, inaccessible, unsatisfactorily air conditioned space" in which the pilots worked.

What are the causes of fatigue? We are all familiar with fatigue resulting from work. We know that the longer and harder we work, the more tired we become. There is, however, no reason to believe that more physical effort is required to fly a jet airplane than a conventional one. On the other hand, other things than physical effort can cause fatigue. It is well known emotional conflicts and frustrations can make us tired. This is the principal symptom of the most common psychoneurosis and in a mild degree is probably experienced by most of us.

Personal and social conflicts induce stresses which are every bit as fatiguing as hard work and much more difficult to get away from. One of the most objective statements a man can make after an argument with his wife is, "You make me tired."

Traced To Tension

There is a good deal of evidence that emotional tensions not unlike those aroused by fear and frustration exist in flying jet aircraft. It seems very probable, therefore, that the fatigue is a result of tension rather than work. That is not to say that it is any less real or important, nor that its effects on behavior may differ from gross muscular activity. That this fatigue is caused by tension is indicated by the following quotations from the ARDC report on *Human Factors in B-47 Operation* (pp. 117-178):

> "A few (5) of those who were tired made comments indicating they flew under a more or less constant state of tension.
>
> "A somewhat larger number (9) gave it as their opinion that flying the airplane, particularly some aspects of its operation such as in-flight refueling, is very hard work—the hardest kind of flying they had ever done . . .
>
> "It may be premature, therefore, to hazard the suggestion that when individuals report that they become excessively tired in the airplane the fatigue they are describing is only partly a physiological fatigue and is to a greater extent psychological in origin—a nervous fatigue, the product of tension, of lack of confidence that one has mastery of the airplane, and of the fear that the situation may go wrong very rapidly and that one had better be instantly ready to meet the emergency.

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"It is well known that such conditions of intense concentration and psychological tension cannot be maintained for long periods of time without inducing strong subjective feelings of fatigue. This situation would fit admirably with the statements made by some that they get tired two or three times as fast in the B-47 as in previously flown bombers; or that '5-7 hours in this airplane is equivalent to 18-24 in the B-29' . . . It would also fit in very well with the almost emotional outbursts that were sometimes made against some or all items of personal equipment, some instrument or other, or against temperature conditions prevailing—although these are not to be minimized as irritants or discomforts.

"The point to be made is that items which would be merely annoyances or inconveniences to the relaxed, confident, unworried pilot become aggravated assaults against his safety and well-being to the man who is doing a very exacting job which demands all his attention and energy."

The demands upon the jet aircraft pilot are obvious, as are the ways in which they differ from those upon pilots of conventional aircraft. Primarily they result from the factors of altitude and speed. The potential hazards are greater and the pressures of time and precision are greater. Many pilots undoubtedly are greatly concerned with survival at altitudes of 40,000 feet.

Anxiety Factors

Loss of pressurization at the altitude of jet operation undoubtedly is a source of anxiety to most pilots, and there is undoubtedly a much greater concern with the hazards of possible bail-out than in aircraft operating at lower altitudes. No matter how confident the pilot is in the soundness and reliability of his airplane he is always aware that just outside the plexiglass there is a most inhospitable environment. It is not surprising, therefore, that many pilots react to this awareness with increased tension.

The great increase in speed of jet transports over the more familiar propeller-driven variety adds to the pressures on the pilot. At altitude, speed in itself is of little concern, although approach and landing speeds clearly may be sources of anxiety. Speed, however, means less time and less time results in increased demands on the pilot. Decisions which in slower aircraft may be somewhat leisurely, and may result in "no sweat" for the pilot, must often be split-second in their timing and even more accurate than in the case of slower transports. Moreover, many decisions in jet aircraft are irreversible. The most obvious example is the decision to make an approach and land, particularly if the approach involves penetration of an overcast. Fuel consumption rates dictate that such a decision must almost certainly be correct the first time it is made.

Mid-Air Collision Problem

A problem of increasing importance in modern air travel is the hazard of mid-air collision. A considerable number of collision accidents have occurred during recent months and the data on near misses is alarming. The Air Transport Association has been collecting reports on near misses. Evidence indicates an average of four per day in situations where airline aircraft were involved. Increasing speeds, greater traffic, particularly near cities and airports, and the increased need for instrument operation, all contribute to the hazard of collisions. This is complicated by the varying speed of different aircraft, and by the problems of traffic control under instrument conditions. New methods of control will obviously have to be developed as jet transports become more common. Holding patterns, as now organized, will become impracticable and the new methods will probably result in increased pressures on both ground personnel and pilots.

Much has been made in recently published articles of the reaction time limitations in modern high-speed flight. The time required for perception of other aircraft, decision, movement of controls, and change in the path of the aircraft may well exceed the limits of escape from an accident, if high-performance aircraft should be operating on a collision course. Certainly, greater attention to this hazard will be required during some phases of flight. It seems inevitable that an effective collision warning system must be developed, and that ground surveillance and control must be further perfected.

Another aspect of jet transport operation, which will add to the pressures on the pilot, has to do with cruise control. The complexity of the variables involved in engine operation limit the control which can be exerted by the flight engineer. At the same time flexibility is greatly reduced. For example, under circumstances where maximum endurance is called for, a gain of not more than 20 per cent is possible. The pressures imposed by this narrow margin under circumstances of unpredictable weather are obvious.

Pilots experienced in the operation of propeller-driven aircraft often find the transition to jets a period of much strain and stress. The sensations they experience are new and different, and sometimes disconcerting. They sometimes report a "feeling that the airplane seems to be getting away from them." Any uncertainty, any feeling that one is not in complete control leads inevitably to anxiety and tension.

It is certainly not unreasonable that all of these pressures and demands on the pilot increase the probability of tension fatigue. If we add to this any stresses arising out of home and family situations, military or financial problems, ethical or philosophical conflicts, the resulting fatigue and its accompanying reduction in competence and efficiency are of serious concern.

Work Fatigue

Everyone is familiar with the symptoms of work fatigue. We recognize the sensation of tiredness of muscles, the feeling of lassitude, and the sometimes overwhelming desire for rest. These ex-

On The Cover

The first commercial carrier to take delivery of the S-58 helicopter is New York Airways, which is now readying the aircraft for regularly-scheduled passenger service in the New York metropolitan area. Other U. S. helicopter lines expect to put this Sikorsky-built plane into service early next year.

A 12-passenger aircraft, the S-58 has provisions for a crew of two. ALPA has emphasized this fact prior to a possible issuance of an exemption, by the CAA Administrator, to the Civil Air Regulation requiring two pilots on all scheduled passenger aircraft, weighing in excess of 12,500 pounds. ALPA saw "a real and unnecessary danger" in single-pilot operation of the S-58 "both day and night, even when the weather is marginal, with 12 passengers aboard, in the very heart of the most congested traffic area in the world."

The S-58 is capable of carrying a payload of two tons, distance up to 100 nautical miles, at a cruising speed of 100 m.p.h. It is powered by a single Wright R-1820 engine, offering 1,525 horse power.

In production for the military since the fall of 1954, the S-58 has been delivered in quantity to the Navy as the HSS-1, and the Army as the H-34. The aircraft is also scheduled for delivery to the Marine Corps as the HUS.

periences are equally present when the fatigue results from tension, and are often more prolonged and difficult to eliminate. Wherever anxiety and other emotional problems contribute to fatigue, and accompanying inability to relax, to forget even unimportant problems, and to sleep soundly, compounds the tiredness and interferes with recovery. More importantly, there are a number of insidious effects of fatigue, which because they are not recognized at the time they occur, can result in errors and may cause accidents. Sir Frederick Bartlett, whose work for the British Air Ministry has been a pioneering effort in this field, has described some of the constantly occurring effects of fatigue following highly skilled work, which results in progressive deterioration of proficiency. The first of these effects is an unnoticed increase in the range of tolerated error. The person who is tired, without realizing it, becomes more erratic in his responses, more willing to accept deviations in instrument readings from the acceptable standard, and a delayed correction of such deviations. Hauty and Payne of the Air Force School of Aviation Medicine have recently confirmed the finding that errors in response to instrument reading become progressively greater with fatigue. Their experiment covered a seven-hour work period in a laboratory simulation of flight instrument readings, but did not involve the tensions and pressures of actual flying. Even under these circumstances, the errors in reading became progressively greater to an extent which would be of serious consequences if they were duplicated in flight.

A second effect of fatigue which if often unrecognized by the pilot is a gradual loss of timing. The person who is tired has a tendency to make the right response but at the wrong time. There is a tendency for over-correction of controls, and an increase in restless movements. The fatigued person fails to recognize these changes or is willing to accept a lower standard of performance.

The motivational aspects of fatigue also affect the pilot's manner of flying. His desire for rest, and the frustration resulting from prolonged effort and attention often create emotional disturbances, increased irritability, and a tendency to direct aggression toward the airplane, or toward other persons.

All of these fatigue effects are present in current aircraft to one degree or another. Long and strenuous flights will inevitably create the same acceptance of lowered standards of performance and decreased accuracy, as well as motivationally distorted decisions and judgment. It appears, however, that for at least a considerable portion of pilots, operation of jet aircraft intensifies the effect of work fatigue and imposes hazards more quickly and to a more dangerous extent than in conventional aircraft. We should, therefore, consider what may be done to deal with this problem.

One possible approach is suggested by the fact that only a portion of pilots interviewed report experiencing this type of tension fatigue. If we could assume that the 75% of pilots who did not report it were free from the tension, we might develop means of selecting for jet transport pilots those least likely to be affected by these tensions. It is probably unsafe, however, to assume that all those pilots who did not report fatigue were entirely free from tension. Better training would appear to be more promising than better selection.

I would like to suggest that the solution lies generally in two factors: The pilot's confidence in the airplane and his confidence in himself.

Differences In Jet Transports

The jet transport will have in back of it many years of experience in the design of jet fighters and bombers. Moreover, it will be built to provide more comfort, more space, and greater ease of operation. Jet transports will have many advantages over propeller-driven aircraft. Their relative freedom from vibration which will reduce one important contributor to fatigue and stress. The altitudes at which they will be operated will avoid turbulence and result in smoother flights. Moreover, the greater speed and resulting shorter flights will permit more accurate prediction of weather conditions at destination. This together with the altitude will make weather enroute more predictable also.

Jet aircraft are relatively more simple in operation. While there will still be plenty of instruments to read and controls to operate, they will be fewer than in conventional transports, and there will be an increasing tendency to make certain aspects of operation automatic.

There is increasing recognition among cockpit designers that things can be done to improve the effectiveness of the man-machine system to increase compatability of the pilot and the airplane, and to improve the physical environment of the cockpit. Certainly, the jet transports now being developed will have the benefit of work by human factors teams. There is every reason, therefore, for the pilot to be confident that the demands imposed upon him by the airplane, while greater in some respects as compared with conventional transports, are less in other respects, and in total, certainly not in excess of his capabilities.

To maintain his confidence in himself, the pilot must be adequately trained, be physically fit, and mentally fit. It is probable that the best basic training for pilots of jet bombers, and possibly for jet transports, will involve flying other jet aircraft. The T-33 has been recommended, for example, by several long-time bomber pilots as "an excellent introduction to the B-47." It is possible, therefore, that ex-fighter pilots may feel more at home flying jet transports than will ex-pilots of C-97's, 119's, 124's, etc.

It is of utmost importance that the simulators being developed to accompany the jet transports be fully exploited for transition training. The great realism achieved by the modern simulator may well serve to provide an opportunity to overcome the tensions associated with early stages of flying the airplane. Moreover, it is entirely conceivable that pilots incapable of adapting to the demands and pressures of jet operation might be weeded out by observing their simulator performance.

Physical fitness is of greater importance in jet operation than in other aircraft, and adequate sleep and rest is an important aspect of physical fitness.

Mental fitness involves both knowledge and attitude. The pilot who is truly mentally fit to fly knows his airplane, his procedures, and is able to avoid stresses by keeping well ahead of the aircraft.

What Is Needed

Attitudes and emotions need to be well controlled also. To quote a flying safety article on this point, (*Selected Studies, Jet Operations & Flight Techniques,* May 1955, p. 25):

> "An untroubled mind is one of the greatest assets you can have. This is especially true when you consider the mental tasks and reactions required of you while flying. With split-second tasks to perform you may find yourself really behind the eight-ball if you have been flying along worrying about your finances, love life, mother-in-law or other equally disturbing conditions.
>
> "If your problems seem too great

(Continued on Page 14)

On The International Scene

Pilots, Regardless Of Nationality, Need A World-Wide Organization Such As IFALPA Because It Is Their Only Access To International Authority

By Capt. L. Arthur
British Air Line Pilots Association

Invariably, when a member of one of the air line pilots associations within IFALPA, meets a lone IFALPA representative, the thought goes through his mind—"How much does this cost *me*, and is it *worth* it?"

What is this need to represent pilots at international level? What happens after all the interminable wrangling, tact, diplomacy and technical definitions?

Let us look at the globe, detach ourselves from our domestic commitments, and observe the situation as it affects aviation.

Now supposing that each member state of the United Nations Assembly, decided to have its own ATC rules, its own frequencies for communications, its own navigation aids and so forth, and let us suppose that separation standards, airport lighting, runways, were all individual to the states and completely independent of each other. Also suppose some preferred to observe metereological conditions at local times to suit their internal labor situation, and others GMT.

Chaos Seen

It needs no stretch of imagination to conceive the chaos which would reign, and the mass of varying navigation aids, communication equipment and performance characteristics which would literally legislate the airplanes onto the ground. Whether you, as an Association member, object to going part of the way to meet the needs of a foreign pilot, or not, the fact remains that you are both on the same airways system some time in your career, and his wingtip in your cockpit would spoil your day. You are, therefore, somewhat interested parties.

In order to keep your cockpit in some ordered form of layout, you want to be able to concentrate on the smallest variation of landing aids and navigation aids, so some international agreement on what these should be must be agreed, and implemented.

In order to insure that adequate lead-in lighting is supplied, and taxiways and lighting are obtained from the candle-in-the-bottle Asiatic mentality, some standard must be reached, in order to satisfy manufacturer's tenders on a worthwhile scale, and to insure that while one system leads to the middle of the threshold, the chance of another leading into the front of the local mosque is avoided.

IATA's Role

So what, you say? So let IATA take care of all of this!

Commendable as the organization of IATA may be, and adept at conference work as they undoubtedly are—how many of their representatives have the essential background to envisage the way a piece of particular legislation will react in the cockpit?

Very few indeed. Occasionally they call upon individual pilots to advise or speak on their behalf, but curiously enough it becomes apparent that their range of delivery, speed of anticipation in debate, and *breadth of vision* is hampered by the dictates of the brief, drawn up by skilled negotiators and ground-experts—but not air line pilots.

Prayer Of The Air Line Pilots

O Lord, tomorrow I pilot human cargo across the country—please let us live another day.

Let the sun be hidden and skies be cloudy, for I wish to be free from fear, fear that I will crash into a "VFR" plane, whose pilot is more confident in "see and be seen" than I am.

Let the skies be cloudy, from the ground to the heavens, for then no one can venture forth without traffic control.

Let there be "300-3/4" throughout the land, for then I trust my ability and my machine—but I can not dodge bullets.

Please Lord, let there be lousy weather tomorrow.

CAPT. JACK STEIDL
Council 12, UAL

Shackled, tied and hamstrung, the IATA pilot cannot bring the breadth of imagination and creative energy so needed at United Nations level. Here it is that the International Federation of Air Line Pilots' Associations has grown in status. It is rapidly becoming apparent that IFALPA is beginning to bring some of the best arguments to the conference table, without breaking the essential community spirit so necessary to international goodwill.

IFALPA's Status

The status of *your* Federation is exactly *equal* to *IATA* in ICAO.

Don't forget it; it is the pilot's access to International Authority, and whatever may be your opinions of this arrangement, remember, that unless both IATA and IFALPA are agreed upon fundamentals, any proposals for or on behalf of the operators has little chance of becoming a success in plenary session.

Why?

The States have the votes in plenary session, and their votes are conditioned by whether the Treasurer at home can run to the cost. A split front between the two main operational factions does not lead to confidence when large capital sanction is called for.

Legislation For Practical Needs

This does not mean that IATA and IFALPA have to be "out of step," but it does mean that pilots can astutely condition legislation to meet practical needs, and at the same time look ahead into the future and state their views *in advance*. The Annual Conferences of IFALPA are most vital to this concept, and your Association has taken, and is taking, a very important part in these affairs.

Do not pass off their recommendations lightly, and try to remember that there is no loss of sovereignty in agreeing on safe international policy.

There is also another aspect of IFALPA which has been noted quietly at diplomatic levels. It is the ability of IFALPA representatives to mix re-

Contradiction Of Jurisprudence

A Noted Newscaster Decries The Only Crime For Which A Man Is Found Guilty Until He Proves Himself Innocent

By Paul Harvey
ABC News Commentator

The April 1 crash of a TWA airliner at Pittsburgh cost 22 lives.
The CAB picked up the pieces and questioned survivors . . . including the pilot and co-pilot.
And then issued the customary verdict: "Pilot error."

That often-used phrase is almost as often abused.
It's a cowardly way for the living to blame the defenseless dead.
When you charge "pilot error," you are in effect saying: that crew is guilty of negligent manslaughter. Or murder.

There is no other crime in the United States for which we find a man guilty unless he can prove himself innocent.
It's all backward. It is a contradiction of all that's decent, democratic and jurisprudent.

In this case, however, the crew survived.
Yet the Civil Aeronautics Board conveniently ignored their testimony.
Only their union has dared raise a voice in their behalf.
Well, here is one more.
I challenge the validity of that finding.

It has been very painful, ever since Newark, for the accident investigators to remember the runaway propeller.
Or the one that, when fire has hit the wiring, refuses to feather.

The CAB stated that wind and weather had nothing to do with this.
Somebody's getting off too easy.

The transcriptions of tower conversation show . . . that this airplane was given a downwind runway.
And that it took off downwind on instructions from the tower.
And weather recording instruments prove that it was downwind at that time.

If this plane had been taking off upwind . . . where, incidentally, the terrain was much better for a go-around, those 22 persons would almost certainly be alive tonight.
But the error was not in the cockpit.
And some of us won't let those men and their families live out their lives with this unproved accusation of murder against them, without demanding proof.
Or a public apology.

(An excerpt from PAUL HARVEY NEWS *of September 23, 1956)*

gardless of tension at political level, to discuss and live as colleagues and friends in a world of stress. This was probably well understood by the Vatican at the Rome Conference—and its recognition at Papal level is not lost upon the world at large.

It is becoming apparent at long last, to all concerned, that in many cases the internal arrangements within any member state of ICAO, concerned with aviation, are being dictated by events legislated for *outside* their boundaries.

IFALPA's Impact

Thus the adaptation of any IFALPA argument can often guide, indirectly, the interests of a member pilots' Association, within any state so affected.

The member of an Association whose task it may be to represent IFALPA at ICAO level, may often be misunderstood by his colleagues within his Association. That is understandable, as they must think domestically—he must think and act for many nationalities, all who contribute and expect the agreed policy to be properly presented. He must enjoy their confidence, friendship—and guidance. He cannot represent his Association alone, or put forth the view of a minority in KLM, or any other Association, he must, and does, represent the *world* pilots.

Of course at a regional level, he must take considerable note of the pilot-requirements of the particular Region, but here again it should not deviate from agreed policy to the detriment of Federation interests.

ICAO's Role

You may wonder why the same pilots tackle this job, specialize in ICAO Conferences? The reason is that technical know-how, while essential, is not enough. A historical card-index mentality is required for keeping in touch with the varied ICAO Annexes. Ease of speech at the microphone to suit the needs of interpreters and delegates is vital if a point of discussion is not to be lost, or a misunderstanding is to be avoided. Names become known and through constant reference, are associated with the Federation to its benefit; contacts are made which can lead to the settlement of what could become an open controversy, and lead to further thoughts out of the Conference, before presentation before the states concerned. This costs you, as a member, a very small amount per annum. You can have no fear that what becomes IFALPA policy will spoil your day; the melting pot of a world-pilot conference leaves little room for a personality cult, or for sectional interests. It can only produce very considered directives, and a stabilizing influence in ICAO, through sound team-work.

You are benefiting in an unseen manner from such a Fellowship, and it is just one more reason why it is wrong for pilots who are not Pilots Association members, to assume that their money can be better used outside an Association such as ours. Remote though ICAO may seem, infant though it may be as yet—it must, and will work for the betterment of the pilots, and for safety in the air in which they serve. You are a member, as a member of your Association. There is no other body which can do such a job for you.

(From THE LOG, *Official Journal of the British Air Line Pilots Association)*

Crash-Resistant Fuel Tanks

Among Serious Air Transport Crashes Are Those Which Would Be Survivable Except For Fire. A Progress Report On Work To Eliminate Fuel Tank Fires

By C. V. Bennett and R. J. Schroers

CAA Technical Development Center, Structures Branch—Aircraft Division

Among the serious aircraft transport accidents are those in which personnel survive the actual impact of the crash, but do not survive the fire following the crash. Available data for domestic and international scheduled passenger air carrier operation from January, 1938, through June, 1951, show that crashes not followed by fire were fatal to 60.8 per cent of the occupants. In the case of crashes followed by fire, the fatality rate jumped to 84.6 per cent. This indicates that the difference, 23.8 per cent, may have been due to fire.

Aviation people have been wanting, but hardly daring to hope for, a solution to the crash-fire problem as far back as World War I. There is evidence that some early efforts were made from time to time both in this country and abroad to solve the problem, but without success.

In an effort to reduce the fire hazard during airplane crashes, the Civil Aeronautics Administration at its Technical Development and Evaluation Center in Indianapolis is conducting a test program in cooperation with the Goodyear Tire and Rubber Company, and the United States Rubber Company to develop aircraft fuel tanks which would resist rupture during crash conditions to a much greater extent than present tanks, thereby preventing the spread of fuel and the occurrence of destructive fire. It now is possible to report that this work is approaching completion, with the flexible bladder cell type of tank emerging as a very promising solution to the crash fire problem. While final numbers must yet be reduced from test data, those that are available indicate that a very substantial degree of crash-resistance can be achieved in such tanks without an unreasonably high weight penalty.

Ways Toward Solving Problem

Information which has led to a solution of the problem has been obtained from several sources; namely:

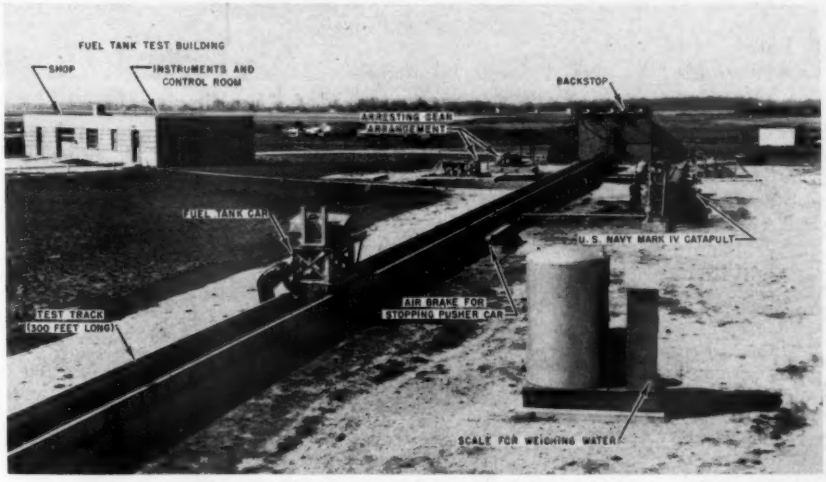
- Studies of existing accident data,
- Investigation of accidents as they occur to determine the types and extent of damage suffered by fuel tanks during crash conditions,
- A program of testing many types of fuel tanks and supporting structures, in order to learn as much as possible about the strength of present tanks and the manner in which they break under simulated crash conditions,
- The burst testing of prospective flexible bladder cell materials on a very large and powerful compressed air gun to determine those materials which are likely to have optimum crash-resistant properties, and
- The impact testing under simulated crash conditions of full size flexible type fuel cells made of the best materials as determined from tests on the compressed air gun. These fuel cells were installed in typical aircraft wing structures for the tests. The results of the simulated crash tests are then to be applied in a more or less rational manner to aircraft under actual crash conditions.

While the work of determining the required strength and energy absorbing properties of crash-resistant fuel cells in wings is nearing completion, the problem still remains of developing fittings and accessories which will not tear or otherwise jeopardize the crash-resistance of the fuel cells. The use of automatic quick disconnect self-sealing features, a "weak-link" in mounting structure, integral construction of fittings with the tank itself, or the equivalent, appears to be a way of solving this problem.

Accident Investigation Findings

The following has been learned from accident investigations:

- Severe damage may be incurred by the wing structure, where fuel tanks are presently located, while relatively little damage may occur to the fuselage structure and few personnel may be lost as a result of the crash impact.
- Although the fuel tanks and supporting structure in each crash may be subjected to many combinations of impact and inertia forces, the forces in wing and fuel tank structure can be resolved into a few basic types. These are:
  1. Fuel inertia forces resulting from deceleration.
  2. Fuel pressure forces resulting from a change in shape or decrease in volume of the tank.
  3. Direct impact upon the leading edge or lower surface of the wing in the region of the fuel tank by



Facilities for conducting crash tests of aircraft fuel tanks.

Jet Familiarization

Representatives from ALPA's jet aircraft technical committees get briefing from Maj. Tennyson, SAC-USAF, (foreground) during visit of SAC Castle Air Force Base at Merced, Cal., to review SAC experiences in pilot training and jet operation information. Others shown (l. to r.) are: E. O'Donnell (CAP), F. L. Wallace (PAA), P. Koehn (CAP), E. J. Bechtold (EAL), J. Meek (DAL), W. H. Records (AAL), Col. Schleeh, SAC, C. F. Eck, ALPA Engineering & Air Safety Dept., C. G. Sperry (UAL), Maj. A. Silva, SAC-USAF.

Convair 880 Mockup

The Convair 880 cockpit mockup was inspected during first meeting of ALPA Convair 880 Evaluation Committee at manufacturer's San Diego plant. Shown in front of mockup are (l. to r.): H. King, Convair design staff engineer; T. G. Linnert, Head, ALPA Engineering & Air Safety Dept.; L. DeCelles (TWA), H. H. Thurston (TWA), J. J. Meek (DAL); in foreground: R. F. Adickes (TWA), Committee Chairman; R. D. Potter (DAL).

The ALPA Camera

ALPA Trophies At Model Meet

Capt. R. J. Geren (BNF) is shown as he presented the five trophies for the events ALPA sponsored at the recent National Model Airplane Championships Meet in Dallas. This annual competition of the Academy of Model Aeronautics has gained wide appeal among the nation's air-minded youth. Shown clock-wise with Capt. Geren are (l. to r.) the winners of these contests: "Indoor Hand Launch Glider—Open," Bob Hanford, Lawrence H. Conover, S. B. Savage, USAF Team; "Indoor Hand Launch Glider—Jr.", Dick Mathis, Robert Cobb; "Indoor Hand Launch Glider—Sr.", Johnnie Werts, Curtis Stevens; "Limited Glider—Sr.", Ed Christianson, Neal Henderson; "Limited Glider—Jr.", Burton Grant, Dick Mathis, Billy Bell.

an external object.

4. Bending, torsion, or combined bending and torsion of the wing as a whole.
5. Impact loads applied directly to fuel bulkheads by landing gear attachments on the bulkheads.

▶ The spanwise locations of the fuel cell in the wing is a factor which affects the severity of the crash from the standpoint of fuel cell damage. Twisting, bending, and direct shear loads on the wing from impact forces usually result in failure of the wing at the inboard end, rather than near the outboard end of the wing. This indicates that fuel tanks should be located in outboard rather than inboard portions of the wing.

▶ Fires resulting from a failure of outboard tanks may not be as serious as those resulting from failure of inboard tanks, since they are farther from the cabin and may allow greater time for escape and rescue.

▶ Crash experience with some military aircraft has indicated that mid-wing and high-wing aircraft experience less damage to the wing structure in crashes and fewer serious crash fires than low-wing aircraft, because the wing tends to stay away from the ground in higher wing type aircraft. However, the higher wing position tends to lead to greater damage to the fuselage than in low-wing aircraft. From the over-all crash standpoint, neither type aircraft appears to have any real advantage over the other, as far as crash safety of personnel is concerned.

▶ Wings having low slung nacelles, and high wing dihedral starting at the root may experience less wing damage in crashes and fewer serious crash fires. These features again tend to keep the wing away from the ground during a crash.

▶ Impact forces on a wing during a crash are principally in a rearward and upward direction. Inertia forces resulting from deceleration are in a forward and downward direction. These conditions are realized in the majority of cases.

▶ Crash fires may be fed by broken fuel lines, even though the fuel tanks are intact and not leaking after the crash impact. Although fires from such sources build up to large magnitudes more slowly than when failure of the fuel tank is involved, and permit more time for escape and rescue, they can spread swiftly to the fuel tanks, and result in rapid destruction of the aircraft.

Fuel lines are known to have broken numerous times in the nacelle, as a result of engine movement, but they can be broken between the engines and tanks and between tanks themselves.

▶ Ignition of fuel results from hot engine parts, flame in the engine exhaust and intake systems, sparks from the engine ignition system and engine electrical accessories, broken wires in the airplane electrical system, sparks from striking metallic parts and electro-static discharge. In actual crashes, it is not generally known how ignition is obtained, but it is generally accepted that the engine is the most probable source of fuel ignition.

▶ Tanks containing other flammable fluids, such as lubricating oil and hydraulic fluid, offer a serious hazard as a source of small fires which can spread rapidly to the fuel tanks, thereby precipitating destructive fire.

Test Facilities

The facilities at the Technical Development Center for fuel tank tests are shown in an accompanying photograph. The Navy Mark 4 catapult serves as the power impulse through a system of cables for a carriage which runs on a track 300 ft. in length. The fuel tank to undergo tests is placed on the carriage, the catapult air valve is triggered, and the carriage is projected down the track at desired velocities up to 100 mph. The tank can be brought to a sudden stop near the end of the tracks by the arresting gear at the foot of the track, or can be allowed to slide from the carriage and crash into the back stop. In these tests, water, rather than fuel, is used in the tanks.

The catapult equipment is capable of accelerating a load of about 2,500 lb. to a maximum velocity of 100 mph., and can accelerate a load of 6,000 lb. to about 65 mph. The arresting gear or deceleration equipment can stop a load of 6,000 lb. at 15 g, and, depending on the weight of the test article and its projected velocity, it can be used over a range of approximately 8 to 30 g. The backstop arrangement utilized for impact tests at the end of the track can be used as a flat surface or obstacles of various shapes can be fastened to its steel face. This combined test facility allows a wide range of test conditions using tanks having a maximum capacity up to 500 gal., depending on the type of tests conducted and the test velocity desired. For the last series of impact tests, sandbags were placed against the backstop and the tanks were propelled into them.

Early Crash Test Conclusions

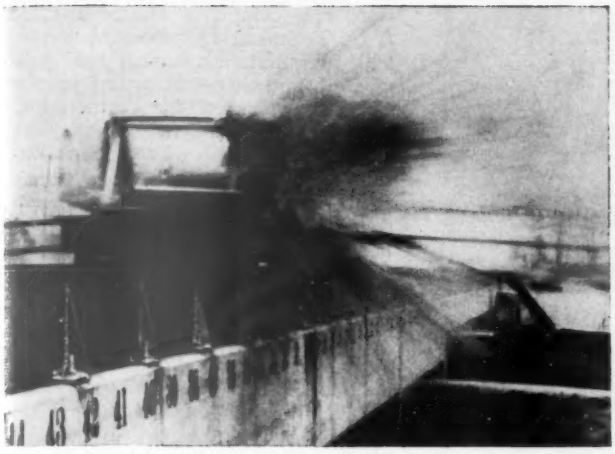
In early tests, some 250 fuel tanks of all types were subjected to various crash tests. Two examples of these, a typical deceleration test, and a typical impact test are shown in adjoining photographs. The details of these tests have been reported at the SAE National Aeronautics Meeting in Los Angeles during October, 1951. Consequently they are a matter of record, and it is not believed essential that the details be repeated here. Suffice it to say, that a number of important conclusions were drawn from them.

The most important statements

17 Ways To Harm Your Union

From LABOR'S DAILY

1. Don't attend meetings, but if you do, arrive late.
2. Be sure to leave before the meeting is closed.
3. Never have anything to say at the meeting—wait until you get outside.
4. When at the meetings, vote to do everything. Then go home and do nothing.
5. The next day, find fault with the officers and your members.
6. Take no part in organization affairs.
7. Be sure to sit in the back, so you can talk it over with a member.
8. Get all the organization will give you and don't give the organization anything.
9. Never ask anyone to join the organization.
10. At every opportunity threaten to resign. Try to get others to do the same.
11. Talk cooperation but don't cooperate.
12. If asked to help say you haven't time.
13. Never read anything pertaining to the organization.
14. Never accept an office since it is easier to criticize than to do anything.
15. If appointed to a committee never give any time or service to it.
16. If you receive a bill for dues ignore it.
17. Don't do any more than you have to, and when the others willingly and unselfishly use their ability to help the good cause along, then howl because the organization is run by a "clique."



Fuel Tank in Deceleration Test.

Fuel Tank in Impact Test.

which can be made in summary of the early crash tests with regard to crash fire hazards of fuel tanks are:

▶ No design of fuel tanks in use in present transport-type aircraft will withstand, to any reasonable degree, the forces which are encountered in crashes where personnel normally can be expected to survive the crash impact. This refers to the case where high, local impact forces are obtained on the wing at the fuel tank location, or where the wing tends to break off through the fuel tank section.

▶ No present design of fuel tanks in use today is significantly better in this respect than any other type.

▶ During crash conditions of the type under consideration, some portions of the aircraft structure are, on the average, subjected to lesser or greater loads than others. Whereas in one location a relatively lower strength and lower weight tank might be satisfactory, a higher strength, heavier tank would be necessary to provide equivalent protection when installed in a more vulnerable location.

▶ It is believed that if:

1. The tank is placed outboard in the wing at a location where breakage probably will not occur,
2. The tank is placed behind a reasonably heavy spar and leading edge section to absorb direct impact,
3. An underslung nacelle is used, which tends to keep the wing away from the ground.
4. The tank is designed to withstand high impact and deceleration loads, and
5. Landing-gear leads are not applied directly to the tank structure,

then the most favorable circumstances are secured for the prevention of fuel tank crash fires.

▶ Flexible bladder tanks, which are free to shift in the structural compartment, and which possess sufficient strength and energy-absorbing properties to resist rupture when the surrounding aircraft structure disintegrates, offer the most promising and readily available structural solution to the fuel tank crash problem.

▶ Fuel lines should include automatic disconnect couplings at proper locations which seal the fuel in the lines, should such lines be broken due to separation of the engine from its mount, shifting of fuel tanks, structural breakage, etc.

Another important conclusion which was subsequently derived from the tests is that among the various types of loads which can be experienced by wing fuel tanks during crash conditions, the concentrated type of impact load on the leading edge or lower surface of the wing in the region of the fuel tank is the most severe condition and should be considered as the design condition for the tanks. Consequently, in the last series of tests, impact tests against the backstop have been used exclusively in the experimental work.

Basic Concepts Of Test Program

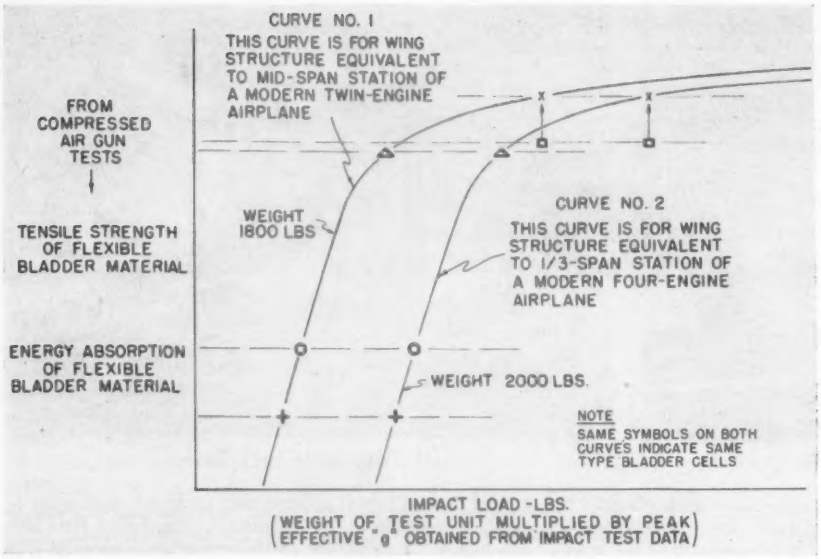
▶ **Crash Loads on the Structure:** In the early planning for this project, much discussion was carried on in an attempt to determine how "strong" a crash-resistant tank should be. There appeared to be no available data which could be used as a reliable guide in answering this question, but it was clearly evident and accepted from the very beginning that it is unreasonable to attempt to prevent the rupturing of fuel tanks during crashes of such severity that personnel have no chance of survival from the crash impact. Therefore, it was initially concluded that the objective of the program would be the development of fuel tanks which could resist rupture under only moderately severe crash conditions. This thinking has undergone some continual transition and has progressed to the present and perhaps more rigorous concept that fuel cells should be capable of resisting rupture in the types of accidents and crashes in which the passengers would normally be expected to survive the crash impact.

With this in mind, so-called rational design criterion has been adopted which defines a representative type of survivable crash condition for the development of crash-resistant fuel tanks in wings. It is as follows:

> Crash-resistant fuel tanks in wings should not rupture from the effects of impact loads having sufficient magnitude to tear the wing from the aircraft. In this type of crash it is assumed that the aircraft is under control of the pilot and making an emergency landing in moderately rough terrain.

From an analysis of the chordwise strength of wings, and formal actual crash experience, it is known that the wings can be torn from an aircraft without imposing high inertia loads on passengers in the cabin. In many instances the passengers would hardly be more than jostled.

If the wing, where most of the fuel is now carried, is torn from the aircraft, it is generally conceded that the major fire hazard is removed from the passengers. While this certainly is not always true in actual crashes, it has sufficient merit to be presented in support of the overall argument. Insofar as the basic concept itself is concerned, there seems to be no valid reason for


CURVE NO. 1
THIS CURVE IS FOR WING STRUCTURE EQUIVALENT TO MID-SPAN STATION OF A MODERN TWIN-ENGINE AIRPLANE
FROM COMPRESSED AIR GUN TESTS
TENSILE STRENGTH OF FLEXIBLE BLADDER MATERIAL
ENERGY ABSORPTION OF FLEXIBLE BLADDER MATERIAL
WEIGHT 1800 LBS
CURVE NO. 2
THIS CURVE IS FOR WING STRUCTURE EQUIVALENT TO 1/3-SPAN STATION OF A MODERN FOUR-ENGINE AIRPLANE
WEIGHT 2000 LBS.
NOTE
SAME SYMBOLS ON BOTH CURVES INDICATE SAME TYPE BLADDER CELLS
IMPACT LOAD - LBS.
(WEIGHT OF TEST UNIT MULTIPLIED BY PEAK EFFECTIVE "g" OBTAINED FROM IMPACT TEST DATA)

Crash Test Results.

using impact loads greater than those necessary to tear the wing from the aircraft. On the other hand, loads less than this would concede the rupture of fuel tanks with the wing still attached to the fuselage.

It is interesting to note that any inertia loads which can be transmitted to passengers in the cabin by loads applied to the wing in a chordwise direction, are not sufficiently high to break the seat belts. This means that, insofar as overall crash survival for passengers is concerned, there is no relationship between seat belt strength and fuel tank crash-resistance.

▶ **Loads on the Flexible Bladder Cell Tanks:** In the case where the aircraft structure surrounding a bladder type fuel tank is so damaged during an actual aircraft crash by impact with some external object that openings are created in the structure, the bladder tank must remain intact and must prevent any appreciable loss of fuel if the danger of destructive fire is to be averted. The work absorbed by the bladder-cell material covering a relatively large opening in the metal structure is a function of the mass of fuel behind the opening and of the deceleration of that fuel mass during the crash impact. A major consideration in achieving a crash-resistant, bladder-cell tank therefore, is the attainment of a material which is capable of absorbing the work done by the fuel in trying to escape from the tank. This is done by virtue of the strength and of the elongation properties of the fuel-cell material. If the opening in the metal structure is small, very little elongation of the bladder-cell material behind the open seam can occur. In this case it is believed that the strength of the bladder-cell material rather than its ability to absorb energy becomes the predominating factor. Therefore, it is considered that the material which is, for its weight, capable of sustaining the greatest load, able to absorb the most energy, and in addition is as tough as possible in order to minimize the danger of failure from puncturing and tearing action, is the optimum material for use in the fabrication of crash-resistant, bladder type tanks.

▶ **Fittings and Accessories:** Crash-resistant fuel tanks, in order to furnish maximum protection against crash-fires, should be equipped with fittings and accessories which will not tear them or otherwise detract from their crash-resistance. In crashes, forces exist which tend to move the tanks in any relative direction with respect to each other. The use of automatic quick disconnect self-sealing features, weak links, mountings which tear loose from the structure without tearing the cell, integral arrangements of tank and fittings, etc., in all fuel cell couplings, fittings and accessories, is believed to be the means of proving the added crash-resistant qualities to the cell.

Final Phases Of Test Program

In order to determine the optimum materials for crash-resistant fuel cells, some 32 prospective fuel cell materials composed of various configurations of rubber and rubber impregnated nylon and cotton fabrics have been tested on a large compressed air gun. From these tests, now completed and reported in CAA Technical Development Report 220, four materials having very good strength and energy absorbing properties were selected for further tests under simulated crash conditions.

Full size fuel cells made of these materials having a capacity of 180 gallons each, were fabricated for the tests. The cells were delivered into four groups of ten each, with each group having strength and energy absorbing properties different from those of the other groups.

Metal structures of two different categories were fabricated to accommodate the cells for the impact tests. One half of the metal structures is designed to be equivalent in strength and general arrangement to that of the mid-span station of the wing of a modern twin-engine airplane. The other group of structures is equivalent to the ⅓ span station of the wing of a modern four-engine airplane.

Although the impact tests have been completed, the numerical results will not become available until the analysis of the tests has been accomplished. However, the trend of the test results is presented in the accompanying chart. Comments on those results are as follows:

▶ The strength and energy absorbing properties of the flexible bladder materials, as determined on the compressed air gun, are plotted along the ordinate. The impact loads imposed on the test specimens during impact tests are plotted along the abscissa.

▶ Curve No. 1 is for a metal structure equivalent to that of the mid-span station of the wing on a modern twin-engine airplane. Curve No. 2 is for a metal structure equivalent to the ⅓ span station of the wing on a modern four-engine airplane. It is of particular interest to note that no great amount of puncturing or tearing of the tanks was experienced in these impact tests.

▶ The same symbols +, O, Δ, □, on both curves indicate respective positions of the same type bladder cells on each of the two curves.

▶ The separation between the curves is small, which should make it relatively easy to interpolate between the curves and to accurately extrapolate for any category of wing structure.

▶ The chart provides information on the strength and energy absorbing properties which should be embodied in bladder cells to enable them to resist rupture under any impact load. By entering the figure with the impact load required to tear the wing from the aircraft, and by interpolating the curves for proper category of wing

structure, a bladder cell capable of resisting rupture under impact loads of such severity should be realized.

▶ Certain adjustments and corrections must be applied to the curves in order to determine the strength and energy absorbing properties of fuel cells for actual aircraft. Information and data on these corrections are being obtained through impact tests on aircraft models having wing stiffness and properly proportioned and distributed mass characteristics equivalent to that of the modern twin-engine and four-engine transport airplanes mentioned above. The corrections are a function of the mass of the airplane versus that of the test unit, inertia loads which would be imposed on each of them by any magnitude of impact load, wing span-wise strength and flexibility in the chordwise direction, span-wise mass distribution, and position of the fuel cell along the span of the wing. Generally speaking, it appears that the bladder-cell strength required for actual aircraft is well below the strongest cells used in the tests. On the basis of incomplete test data, but in the interest of providing a rough idea on what crash-resistant fuel cells may be expected to weigh, it appears that the average unit weight of well designed crash-resistant flexible type bladder cells having a length of four feet in the longitudinal direction should be somewhere in the order of 0.30 lbs per sq. ft. It is emphasized that this must not be considered a final weight figure. Until such time as complete test data are obtained and analyzed and the results applied to a considerable number of aircraft, final weight figures cannot be known. For some aircraft the weight will probably be less, for others it may be more. The weight may also vary along the wing span for each aircraft.

▶ It is of interest to note that for an average fuel cell weight of 0.30 lbs. per sq. ft., the weight penalty for a certain twin-engine airplane now engaged in scheduled air carrier service, equipped with flexible bladder type fuel cells, would be approximately 130.0 lbs. This is exclusive of any weight penalty that may eventually be necessary for crash-resistant fittings and accessories for such cells.

This concludes the statements which can be made at this time on the results of the recent crash tests.

Regarding fittings and accessories for crash-resistant fuel cells, a guiding concept for their design has been established. Under it, a crash-resistant fuel cell employing the desired type of fittings and accessories is visualized to be able to unhook, unsnap, uncouple itself, etc., from adjacent tanks and from the surrounding structure during crash conditions, and roll free of the damaged structure with the fuel sealed inside the cell. This is, obviously, an objective which cannot be fully attained. Nevertheless, the above description explains the basic objective on fittings and accessories. Work on the fitting problem has already started and every effort is being made to develop the necessary equipment as soon as possible. Obviously, compromises will have to be made. The problem must also be solved without over-complicating the fuel system or jeopardizing its reliability in service.

Studies Summarized

The most important statements which can be made in summary of the studies, investigations, and tests conducted to date are as follows:

▶ The flexible bladder type fuel cell having certain strength and energy absorbing properties has emerged as a very promising solution to the crash fire problem.

▶ A high degree of crash-fire protection can be achieved with such tanks without an unreasonably high weight penalty.

▶ For the most possible crash-fire protection, the fuel cells should be equipped with fittings and accessories which will not tear the cells or otherwise detract from their crash-resistance, during crash conditions.

▶ For maximum crash-resistance, bladder cells should be used throughout the wing. However, integral tanks in outboard areas would provide considerable crash-fire protection by virtue of their location.

▶ It is believed that crash-resistant fuel cells may allow fuel to be carried in the fuselage areas of aircraft with relative safety.

▶ With at least one solution to the crash-fire problem at hand, the aircraft industry can look to the task of improving the crashworthiness of the rest of the airplane with renewed vigor.

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An airline pilot himself, Binder said that "a retired airline pilot's many years of valuable experience can qualify him for an important administrative position in charge of a corporation's aviation department. Compensation in most cases is quite substantial, and coupled with retirement benefits, provides an excellent income."

Pilots Employment Agency furnishes 80% of all corporate aircraft owners with aviation personnel. It has offices at Burbank and Teterboro.

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Crash-Resistant Fuselage Tanks

Work on the development of crash-resistant fuel tanks for fuselages of fixed-wing aircraft has been underway at the CAA Technical Development and Evaluation Center in Indianapolis since July, 1955. The work is being done in conjunction with a program sponsored by the Department of the Army to develop crash-resistant flammable fluid systems for aircraft, including helicopters.

The technical concepts being used for this work are based on experience gained from the work on development of crash-resistant fuel tanks for wings of aircraft.

The work, which is making rapid progress, has involved both the conduct of experimental tests and the study of accidents as they have occurred to determine the nature and extent of damage, and, insofar as possible, the magnitude of load factors suffered by fuselages in survivable type crashes.

Psychological Aspects . . .

(Continued form Page 4)

for you to solve, if you should worry constantly, you'd better take them to your banker, lawyer, doctor or chaplain. It's a cinch you shouldn't fly under mental strain. It leads to distraction from your normal functions, doping-off and, if continued, to a case of psychoneurosis. Then if you haven't fouled-up enough in the meantime to need an undertaker, you'll probably require the services of a good psychiatrist."

Summary

To summarize: It is important to remember that stresses affecting pilot performance exist in all aircraft and that they are intensified in the modern high-performance jet airplane. These stresses are distracting; they result in decreased standards of performance and tolerance for error. As a result they are detrimental to flight safety. They are not only detrimental individually but they also may cumulate to such an extent that accidents may result. Better selection and training will help to prepare the pilot to handle these stresses, and maintenance of good physical fitness and mental fitness are essential.

(From a paper presented at MATS Safety Conference, Honolulu, Hawaii, 1956.)

STATEMENT REQUIRED BY THE ACT OF AUGUST 24, 1912, AS AMENDED BY THE ACTS OF MARCH 3, 1933, AND JULY 2, 1946 (Title 39, United States Code, Section 233) SHOWING THE OWNERSHIP, MANAGEMENT, AND CIRCULATION OF

The Air Line Pilot, published monthly at Chicago, Illinois for Oct. 1, 1956.

1. The names and addresses of the publisher, editor, managing editor, and business managers are: Publisher, Air Line Pilots Association, Int., 55th St. and Cicero Avenue: Editor, Ed Modes, 55th St. and Cicero Avenue; Managing editor, None; Business manager, None.

2. The owner is: The Air Line Pilots Association, 55th St. and Cicero Avenue; Clarence N. Sayen, President; Charles E. Beatley, First Vice President; F. A. Spencer, Secretary; D. J. Smith, Treasurer; all of 55th St. and Cicero Avenue.

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(Signed) ED MODES, Editor.
Sworn to and subscribed before me this 11th day of September, 1956.

(Seal) JANET PUTZ.
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Flier's Forum

Comments On 'Fatigue And Flight Time Limits'

Editor, THE AIR LINE PILOT
Dear Sir:

The August issue of THE AIR LINE PILOT contained an article named "Fatigue and Flight Time Limits." I was most pleased to find the article there, since I have believed for a long time that pilots generally and the ALPA in particular have been most remiss in problems related to flight fatigue. I cannot say I was pleased with the article itself. It contained some truth, but also some dangerous errors.

One of these is this paragraph: "During the last decade improvement in navigational aids, aircraft performance, automatic pilots, improved instrumentation, pressure cabins with air conditioned working quarters, better meteorological forecasting and communications, among others, have reduced anxiety and relieved tension for crews."

I could spend some time discussing this paragraph fully. There is hardly anything in it with which I agree. But to save space, I will only point out that increasing the performance of aircraft increases the burden on the pilots by giving them a machine which goes faster, makes wider turns and because of its speed makes them work faster at everything they do. And the problems connected with operating these high-performance aircraft to lower and lower minima is aggravated by the rapidly increasing problem of air traffic, which has grown to such proportions that the North Atlantic, which not long ago was crossed by aircraft perhaps three times a week, is so busy an airway that airplanes frequently have to wait half an hour to send their position reports.

I have been flying for some time now and ever since I started, there have been engineering achievements about to come out which would solve all the problems of flight and make the pilot merely a figurehead, benignly monitoring all the devices which did all the hard work. It is no exaggeration to say that during that period, while great engineering strides have been made, the air line pilot's job is today much harder than it ever has been. I expect that his job will continue to get harder, the more things they invent.

I should like to see the ALPA take the position that since the pilot's work load increases as speed and size go up, that his work hours shall decrease with increases in speed and size.

It has been most disappointing to me that the ALPA has not been more active in this field. It seems to me that an enlightened position, vigorously maintained, on flight time limitations, is at least as important as negotiation on salaries.

A. D. REEDY
Council 36, PAA

14th Biennial Convention

The ALPA Convention will be held at the Shoreland Hotel, Chicago, November 5-9.

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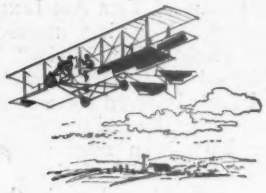

On October 26, 1912, an ungainly biplane swooped into a Michigan pasture like an overfed duck and promptly nosed over on its back. Its contents proved to be a teen-age couple who got married as soon as they regained consciousness.

This was the world's first aerial elopement.

Art Smith, the groom, happened to have one of the country's few flying machines because he had built it, with his own hands, at age 15. And his parents had mortgaged their home to finance him. Their pride helped carry him through years of failure to soaring success as a famous early stunt flyer.

But he didn't remain a barnstormer long. In 1917 his pioneering skill was needed to train our World War I pilots. Then came America's first air-mail service. And again, Art helped break the way—though it eventually cost him his life.

As American as Tom Swift, Art Smith was the farseeing and confident son of a country that has always produced far more than her share of sure-footed visionaries. That's a good thing to know, especially if you've been putting some money into this country's Savings Bonds.

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